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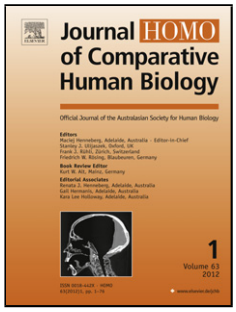

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Secular trends in stature of late 20th century white South Africans and two European populations

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Abstract

During the 20th century a general positive secular trend for stature is observed in developed countries around the world while shorter statures, often associated with a lack of a positive secular trend, have mostly been observed in populations with lower SES. The purpose of this study was to compare secular changes in stature between 20th century South Africans of European descent and two European populations. The comparative samples include Dutch males with which there is an assumed genetic relationship, and Swiss males for which the genetic association is less clear. The sample comprised anthropometric stature data of white South Africans (17 - 62 years), Swiss and Dutch males (18 - 21 years) obtained from military conscripts with birth cohorts of 5 years from 1946 to 1995. The stature of white South African males did not increase at a significant rate compared to those observed in Swiss and Dutch males. South African and Dutch males were of similar height following World War II, but a considerable trend was observed only in the Dutch group. The Swiss group was initially shorter than the South Africans, but due to a positive secular trend their average stature is on a par with that of South Africans in the most recent cohort. The lack of a significant positive secular trend in the South African group could suggest that factors such as gene flow and poor economic and social development in South Africa resulted in shorter statures in white South African groups than expected.

Introduction

Temporal changes in certain aspects of the human body are known as secular trends. The direction and rate of secular trends are subject to change and may also be more pronounced in specific population groups (Henneberg and van der Berg, 1990; Price et al., 1987; Roche, 1979; Tobias, 1985; Tobias and Netscher, 1977; Wolański, 1978). Secular trends could occur in response to variations in living conditions. It is commonly accepted that the direction and tempo of secular trends are a reflection of changes in the socioeconomic situation in a country (Bogin, 1999; Rühli and Henneberg, 2013; Staub et al., 2011). Therefore, the direction and rate of secular trends of population groups usually correspond with the standard of living (e.g., GDP per capita, real wages, access to healthcare and other SES variables) within the country (Bogin, 1999; Bogin et al., 2017; Staub et al., 2011). For example, in countries with high standards of living, marked positive secular trends are expected.

Most studies (e.g., Bogin, 1999; Bogin and Varela-Silva, 2010; Cole, 2003; Eveleth and Tanner, 1976; Federico, 2003; Komlos and Baur, 2004; Komlos and Lauderdale, 2007;

Komlos, 2009; Staub et al., 2011; Steckel 2009) on secular trends in stature across the globe have shown that there is a general trend towards an increase in stature. This can mostly be ascribed to increases in the lower limb length, especially the distal lower limbs (Eveleth and Tanner, 1976; Meadows and Jantz, 1995; NCD Risk Factor Collaboration, 2016). For example, using Dutch male conscript data, it has been shown that the mean height of males has increased from 1860 to 1990 (Cole, 2003). The positive secular trend observed in the Dutch conscripts continued into the 20th century and was even greater after the Second World War (WWII). However, this trend has only been taking place since the mid-19th century. During the 18th century, the mean average heights in many countries decreased due to poor harvests and high grain prices which resulted in poor nutrition during growth. Therefore, the increase in the 19th century is possibly a "correction" of the decreased statures observed in the 18th century (Cole, 2013; Floud et al 1990; Hauspie et al., 1996; Komlos, 1985).

Bogin and Keep (1998) reviewed anthropometric data of individuals from Latin America and found that no secular trend occurred in stature from 1873 to 1989. Between 1898 and 1939 the mean stature decreased followed by an increase from 1940 to 1989. The authors explain that the negative secular trend is probably due to socio-economic factors such as poor health and nutrition during the latter period. The positive secular trend observed from 1940 may have been caused by world-wide economic recovery after WWII (Bogin and Keep, 1998; Bogin, 1999).

Hauspie and colleagues (1996, 1997) have reviewed anthropometric data from children of various countries across the world (Europe and North America, Japan, Taiwan, Cuba, Brazil) as well as living adult stature of Eastern European countries. The same authors and also other researchers observed that, since World War II, a positive secular trend was visible in most Western and industrialized countries (Bogin, 1999; Cole, 2003; Hauspie et al., 1997). The secular increase in stature ranged between 3 mm/decade in Northern Europe (Sweden and Norway) to 30 mm/decade in parts of Southern and Eastern Europe. Countries with smaller rates of secular change in recent years, such as the Scandinavian countries and the Netherlands, appeared to be reaching a plateau of genetic potential for stature. Several other researchers have observed this slowdown in the height trend in recent years in Europe (Larnkjaer et al., 2006; Schmidt et al., 1995; Staub et al., 2011) and North America (Komlos and Baur, 2004; Komlos and Lauderdale, 2007) which indicates that even with increased average income in a country, the population groups can only increase in height until the full genetic potential is reached. However, not enough data are currently available to determine

whether the absence or slowing down of secular trends is short-term due to stabilization in the economy of the countries or whether the trends in stature will change in future due to possible changes in factors such as social inequality or inadequate health care and nutrition (Staub et al., 2011).

Numerous studies in countries with low SES such as India (Vogel, 1971), Peru (Frisancho et al., 1975), Guatemala (Bogin and MacVean, 1984), Mexico (Malina et al., 1980, 1983), Malawi, Kenya, Uganda, South Africa and South West Africa/Namibia (Burgess and Wheeler, 1970; Kark, 1954; Shaper and Saxton, 1969; Tobias, 1975a, 1975b, 1992) have recorded evidence of negative secular trends. Developing countries often exhibit negative or null secular trends in stature. Studies from Guatemala and Venezuela have shown clear patterns of negative secular trends due to a civil war (Bogin and Keep, 1998). Children from all SES groups (high, moderate and low) exhibited a decline in stature as the quality of nutrition as well as the health of the entire population was affected (Bogin, 1999; Lopez-Blanco et al., 1995). Thus, the change in stature may have been more prominent in specific parts of the world while many developed countries have not experienced much secular change recently (Hermanussen et al., 2010; Larnkjær et al. 2006, Staub et al., 2011; Steyn and Smith, 2007).

In South Africa, negative, null and positive secular trends have been reported. Negative secular trends were observed in the stature and proximal lower limbs of black South African groups from the early 20th century (Klark, 1954; Price et al., 1987; Tobias and Netscher, 1976, 1977) while a positive secular trend was observed in the statures of Khoesan individuals (Tobias, 1990). Henneberg and van der Berg (1990) and Louw and Henneberg (1997) observed small increases in the statures of black and white South African males.

Henneberg and van der Berg (1990) measured the living stature of white adult South African groups born between 1880 and 1970. They found that the mean stature of white South Africans increased at a rate of 4.5 mm/decade during this period. Affluent white South Africans had a positive secular trend but did not significantly deviate from a straight line. Although white South Africans have had genetic influences from a variety of sources, there is a very strong link to the Dutch as the founder population and therefore it can be expected that the secular trend in stature may follow that of white individuals living in the Netherlands (15 mm/decade). However, the increase in stature of white South Africans was lower than expected. Overall, the reported secular increases were distinctly lower than those reported in Europe, indicating influences that are specific to South Africa (Henneberg and van der Berg, 1990; Louw and Henneberg, 1997).

This study included medical students who could have been of higher SES than those represented by individuals from military conscript data. Therefore, the aim of this study was to evaluate and compare secular changes in stature of modern South African males of European descent to two modern European groups - a Swiss sample for which there is no clear genetic relationship and a Dutch group with which there is an assumed strong genetic relationship. Data from military sources were used. Additionally, stature data of white South African females were included to demonstrate the current secular changes taking place in white South African groups.

Materials and methods

The data used in this study comprised the average heights of self-classified white South African soldiers from the South African National Defence Force (SANDF) collected by Ergotech (Ergonomics Technologies) which is an ergonomics consultancy company based in Pretoria, South Africa. The data were collected in the late 1980's, early 1990's, 2000 and 2013, and provide the opportunity to assess secular trends in stature. All stature measurements before 2011 were recorded by students from North-West University (Potchefstroom), School of Biokinetics, Recreation and Sports Science. They all had at least a level 1 ISAK (International Society for the Advancement of Kinanthropometry) qualification. From 2011 to present, students from the University of Pretoria, Department of Biokinetics, Sport and Leisure Science recorded the measurements. They were all trained on the required landmark and measurement techniques by an Ergotech research facilitator and their proficiency was evaluated prior to being part of the data collection team.

In order to facilitate accurate measurements, a standardised participant posture and landmark identification procedure was used by Ergotech to ensure that the differences found in body sizes within a group were not due to variations in body posture or landmark marking placements. Stature was measured while the participant stood erect, with their weight evenly distributed on both feet, heels together as close as possible, legs and trunk straight without stiffness, and the head erect and looking straight ahead. The arms hung relaxed with the elbows lightly touching the sides with the palms of the hands beside, but not touching the thighs (Fig. 1). A wall mounted stadiometer was used to measure the vertical distance between the standing surface and the top of the head (vertex) at the maximum point of quiet respiration.

Living human statures of Swiss males and Dutch males between 18 and 20 years were used to compare the statures of recent Europeans with those of white South Africans of European descent. The Swiss and Dutch (Hoogendoorn, 1986) data were obtained from military conscripts (Staub et al., 2015). The measurements for the Dutch and Swiss groups were recorded during a medical examination and included the use of standardised and unmodified anthropometric methods (Staub et al., 2011). Unfortunately, Hoogendoorn (1986) did not state the number of Dutch males used in his analysis. In Table 1, the composition and decades of birth for the South African white male, Dutch and Swiss male samples are shown. The division of the South Africans into various birth cohorts was based on their ages recorded during the survey.

The Dutch and Swiss military conscript data were predominantly comprised of younger individuals (18 to 21 years) while the South African sample consisted of military service men aged 18 to 62 years. Although some males may continue to grow until their early or even mid-twenties (Hulanicka and Kotlarz, 1983), Randall (1949) suggests that any increases in stature after 18 years of age may not be statistically significant. Although not ideal, this allows for comparisons between conscript data and data consisting of service men. It is accepted that the individuals represented in these samples cover the full range of socio-economic strata. This allows general comparisons to be made between the groups. Due to sample size constraints of individuals in each birth cohort for the South African male sample, individuals between 18 and 50 years were used to limit the effect of age-height changes. Stature is known to decrease with age (Chandler and Bock, 1991; Cline et al., 1989; Friedlaender et al., 1977; Galloway, 1988; Giles, 1991; Trotter and Gleser, 1951). However, no samples of this age-range (18 - 50 years) were available for individuals born before 1955 and thus older individuals (50 - 62 years) were used for the 1946-1950 and 1951-1955 cohorts to allow the observation of overall possible differences during this period.

Using the statistical program STATA, the anthropometric stature was compared between white males from South Africa (SAWM), Switzerland (CH) and the Netherlands (NL) for the overall period and by date of birth (DOB) cohorts of five years. Although anthropometric data from females are generally very sparse, data from white South African females were included. Due to the sexual dimorphism in stature no direct comparisons were made, however the data serve to demonstrate the overall pattern of change in stature in both white South African groups. One sample T-tests (two-tailed) were used to assess whether significant differences exist between the means of the groups.

Ethics approval (Ethics reference number 80/2014) for this study was obtained from the Faculty of Health Sciences Research Ethics Committee, University of Pretoria.

Results

Table 1 indicates the sample sizes, average statures and standard errors of the white South African males (SAM) and females (SAF) and Swiss (CH) groups as well as the mean statures of the Netherlands (NL) group (sample size and standard errors not available) per birth cohort.

INSERT Table 1 ABOUT HERE

In both white South African males and females no significant increase in stature is observed from 1946 to 1990 ($p = < 0.0001$). Other than a small increase in the stature of South African females from 1946 to 1960, the pattern is similar to that observed in South African males.

For the overall period, ranging from 1946 to 1995, significant differences ($p = < 0.0001$) were observed between all male groups. Males from the NL group were the tallest with an average height of 1803 mm, followed by the SA and CH males with average statures of 1786 mm and 1765 mm, respectively.

Between 1946 and 1950 and 1951 and 1955, no significant difference was observed between the SA and NL males ($p = 0.505$ and $p = 0.492$, respectively). In the period between 1946 and 1950, South African males were slightly taller (by 12 mm) than the Dutch, while Swiss males were the shortest with a significant difference of 47 mm when compared to South African males ($p = 0.013$). From 1946 to 1980, the average height of CH and NL males increased by 39 mm and 57 mm respectively. However, the average stature of SA males only increased by 9 mm during this period. Over the total period, 1946 to 1995, the average stature of Swiss males increased by 47 mm while South African males had a much smaller increase of only 23 mm.

From 1946 to 1980 the stature of NL males increased by 15 mm, 14 mm, 6 mm, 9 mm, 5 mm and 8 mm respectively for each 5 year period, resulting in an overall stature increase of 57 mm. Although the stature increased during this period, the magnitude gradually declined with smaller increments of stature being observed over time. A similar trend is observed in the Swiss with a gradual increase in stature, but the magnitude has decreased over time (12

mm, 8 mm, 6 mm, 7 mm, 4.4 mm) until a slight plateau phase was reached between 1971 and 1995 (2 mm, 3 mm, 5 mm, 1 mm) when only minor increases in stature occurred.

Figure 1 demonstrates the patterns of secular trends of the mean statures of the three population groups as well as the standard errors for SA males and females and CH males. Due to the large sample size of the CH group, much narrower standard errors than those of SA males are observed. Although SA males were slightly taller than their Dutch counterparts in 1946, due to the lack of a significant positive secular trend in the stature of SA males the NL males overtook the SA males in the period between 1951 and 1955 to become significantly taller ($p = 0.013$) in 1956-1960. Furthermore, by 1981 to 1985, CH males were almost similar in stature to SA males with a difference of only 8 mm. In the 1981-1985, 1986-1990 and 1991-1995 cohorts, the CH group had mean statures that did not differ significantly from those of SA males ($p = 0.076$; $p = 0.083$ and $p = 0.284$). Unfortunately the sample size of the South African males in the last birth cohort is small ($n = 4$). The graph shows an increase in stature for this group, but this remains to be followed up with a larger sample. A summary of the significance values (two-tailed) for the one sample T-tests between SA and CH males and SA and NL males per 5-year period and the overall period can be seen in Table 2.

INSERT Fig. 1 AND Table 2 ABOUT HERE

Discussion

In this study the secular change in statures of white South African males of European descent were compared to two other European samples, namely Swiss and Dutch males. Comparisons of the stature throughout most of the 20th century of South African population groups with European means provide evidence of null secular trends in white South African stature. Many researchers have noted that males are more sensitive to environmental stresses than females (Stini, 1979; Stinson, 1985; Wolański and Kasprzak, 1976). As expected, males were taller than females but both groups exhibited no significant positive secular trends. This clearly indicates that the lack of secular changes was not sex specific but rather a population specific phenomenon occurring in white South Africans.

From 1946 to 1955, thus following WWII, SA males had statures that were similar to those of Dutch individuals. However, the Dutch conscripts exhibited a strong positive secular

trend from the 1940's onwards while a non-significant increase was observed in South African males during this period. Dutch individuals became much taller over time until 1980 when they were significantly taller than South Africans.

Swiss males, who were significantly shorter than Dutch and South African males during WWII, exhibited a strong positive secular trend from 1946 to 1980. Due to the lack of secular trend in the stature of SA males, the difference between the statures of SA males and Swiss males became smaller over time. The stature of Swiss males increased until no significant differences were observed between SA and Swiss males from 1981 to 1995. However, a "genetic plateau" or genetically determined ceiling may be taking place in Swiss males during this period with the increase in stature becoming more gradual. This plateau has been observed in many parts of Europe (Larnkjaer et al., 2006; Schmidt et al., 1995; Staub et al., 2011) and North America (Komlos and Baur, 2004; Komlos and Lauderdale, 2007). Usually the direction and rate of secular trends of population groups correspond with the standard of living, with rapid increases seen in countries with increased average income. However, once the upper limit of the genetic potential for stature is reached, these groups will no longer exhibit marked secular trends (Staub et al., 2011). It seems unlikely that the lack of secular trends in the white South African group is due to this genetic plateau being reached, as SA males are significantly shorter than the Dutch group with whom many share a common ancestral gene pool (Louw and Henneberg, 1997; Price et al., 1987). Therefore, the stature of white South African groups may possibly increase in the future although this needs to be followed up.

The causes of the lack of a clear trend in South Africans in the second half of the 20th century are difficult to explain and are probably multifactorial and complex. Poverty among white South Africans has been well described and became especially evident by the 1880's relating to the First Anglo-Boer War (1880-1881) and the Second Anglo Boer War (1899-1902) (Coetzee, 1942; Terreblanche, 2002; Warwich, 1980). One of the legacies of the Second Anglo-Boer War was the scorched earth policy where farms of 'Boers' were systematically destroyed and burnt and internment camps were erected. This lead to massive displacements and impoverishments after the war. This period was followed by further economic instability brought on by the Great Depression, combined with drought, and WWII.

By the early 1930's, the eradication of white poverty became an objective which led to the first Carnegie Commission investing in the poor white problem (Fourie, 2007). The recommendations from this report included segregation to improve the conditions for white South Africans – of course to the detriment of other populations. In 1948, the policy of

Apartheid was introduced which, among other things, helped to establish white economic empowerment. However, the lack of a significant positive secular trend in white South African groups could suggest that even during this period, the poor economic and social development in South Africa also negatively influenced white South Africans. This may possibly have resulted in the observed shorter statures in white South African groups, although the exact causes remain unclear. According to numerous researchers (Cavalli-Sforza and Bodmer, 1971; McEvoy and Visscher, 2009; Mueller, 1976; Roberts, 1978; Wood et al., 2014), 56% to 99% of the variance in stature is due to heritability while less than 25% is due to environmental influences (Bielicki et al., 1981; Henneberg and van der Berg, 1990; Jedlińska, 1985). However, the increase in stature is significantly less than that of Dutch groups (Bogin 1999; Louw and Henneberg, 1997) or other European groups (Bogin, 1999; Bogin and Varela-Silva, 2010; Cole, 2003; Eveleth and Tanner, 1976; Federico, 2003; Komlos and Baur, 2004; Komlos and Lauderdale, 2007; Komlos, 2009; Meadows and Jantz, 1995; Staub et al., 2011; Steckel 2009).

Henneberg (2001a) has observed a number of instances where the secular trend did not follow the socio-economic change in the country. He suggests that other factors, such as causative agents which either affect or act as a substitutes for the relevant stature determining genes, may be responsible for secular changes in height (Henneberg, 2001a, 2001b). While a slow improvement in socio-economic conditions for all South Africans may be a plausible explanation, other factors such as possible gene flow from other shorter South African groups (e.g. black and coloured South Africans) should be considered (Greef, 2007; Herbert, 1990; Stynder, 2009).

Numerous factors influence comparative studies on secular changes in stature. Although anthropometric standards were used, small differences in the measurements may occur due to interobserver error. One major limitation with comparative studies is the availability of data sets with individuals of comparative ages. Age-height correction factors are often used to account for the decrease in stature with age (Chandler and Bock, 1991; Cline et al., 1989; Friedlaender et al., 1977; Galloway, 1988; Giles, 1991; Trotter and Gleser, 1951). However, these correction factors are population and sex specific and require longitudinal aging data to derive estimates (Giles, 1991). Currently, no correction factors exist for South African population groups. Consequently, data in the 1946-1955 cohorts may underrepresent the actual statures of individuals born during this time as the ages of the individuals ranged from 55 to 62 years. Fortunately, the secular pattern and differences in heights were still observed and important differences between groups were clearly visible.

The factors that influence secular change are complex. The increase in the stature of the Dutch sample has not only been attributed to the rising economic prosperity during the 20th century - improved medical and universal health insurance, welfare support as well as the lower labour force participation of females ensured lower infant mortality rates and improved the environment for growth of children resulting in greater stature (de Beer 2001; de Beer, 2004; Pott-Buter, 1993; van Wieringen, 1972). However, it would appear that generally improved living conditions may not be the major determinant of the direction and magnitude of secular changes but rather particular factors, which are population specific, may be responsible (Henneberg, 2001a, 2001b). It thus remains to be seen how the complex interplay of similar factors in South Africa will influence stature of all South African groups in the coming years.

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Table 1. The mean statures (mm) and standard error and standard deviation of white South African males (SAM) and females (SAF), Swiss (CH) and Dutch (NL) males over 5 year periods (birth cohorts).

DOB	South African Males (SAM)				South African Females (SAF)				Swiss (CH)				Dutch (NL)*
	N	Mean	SE	SD	N	Mean	SE	SD	N	Mean	SE	SD	Mean
1946-1950	21	1782	17.1	78.4	27	1585	6.71	34.9	39947	1735	0.64	65.0	1770
1951-1955	44	1779	8.40	55.7	52	1626	6.77	48.8	38003	1747	0.65	65.0	1785
1956-1960	57	1776	8.84	66.8	90	1645	5.26	49.8	8917	1755	1.33	64.0	1799
1961-1965	59	1782	9.23	70.9	87	1655	5.78	53.9	45977	1761	0.59	65.0	1805
1966-1970	59	1793	7.84	60.2	117	1657	5.32	57.5	41303	1768	0.63	65.0	1814
1971-1975	70	1787	7.05	59.0	165	1670	4.26	54.7	81135	1772	0.45	65.2	1819
1976-1980	70	1791	8.01	67.0	162	1669	4.19	53.3	160576	1774	0.31	65.4	1827
1981-1985	229	1785	4.46	67.6	152	1678	4.46	55.0	168861	1777	0.33	68.1	-
1986-1990	69	1795	7.95	66.0	39	1705	9.14	57.1	179547	1781	0.29	65.5	-
1991-1995	4	1805	17.3	34.5	-	-	-	-	122382	1782	0.37	65.4	-
1946-1995	**682**	**1786**	**2.51**	**65.5**	**891**	**1662**	**1.90**	**57.4**	**886648**	**1765**	**0.60**	**-**	**1802**

*Only mean was available. N – Number of individuals; SE – Standard error; SD – Standard deviation.

Table 2. The significance values (two-tailed) for comparisons of the means of South African (SA) with Swiss (CH) and Dutch (NL) white males over 5 year periods using one sample T-tests.

DOB	SA vs CH				SA vs NL			
	p-value	Mean difference	95% CI of the difference		p-value	Mean difference	95% CI of the difference	
			Lower	Upper			Lower	Upper
1946-1950	**0.013**	46.62	11.00	82.28	0.505	11.62	-24.04	47.28
1951-1955	**0.000**	32.18	15.24	49.12	0.492	-5.82	-22.76	11.12
1956-1960	**0.019**	21.45	3.74	39.17	**0.014**	-22.54	-40.26	-4.83
1961-1965	**0.029**	20.71	2.23	39.20	**0.014**	-23.28	-41.77	-4.80
1966-1970	**0.003**	24.59	8.90	40.29	**0.008**	-21.41	-37.10	-5.71
1971-1975	**0.035**	15.13	1.06	29.20	**0.000**	-13.87	-45.94	-17.80
1976-1980	**0.035**	17.20	1.22	33.18	**0.000**	-35.80	-51.78	-19.82
1981-1985	0.079	7.97	-0.83	16.77	-	-	-	-
1986-1990	0.083	14.00	-1.86	29.86	-	-	-	-
1991-1995	0.284	22.50	-32.46	77.46	-	-	-	-
1946-1995	**0.000**	**21.15**	**16.23**	**26.07**	**0.000**	**-15.85**	**-20.77**	**-10.93**

DOB – date of birth.

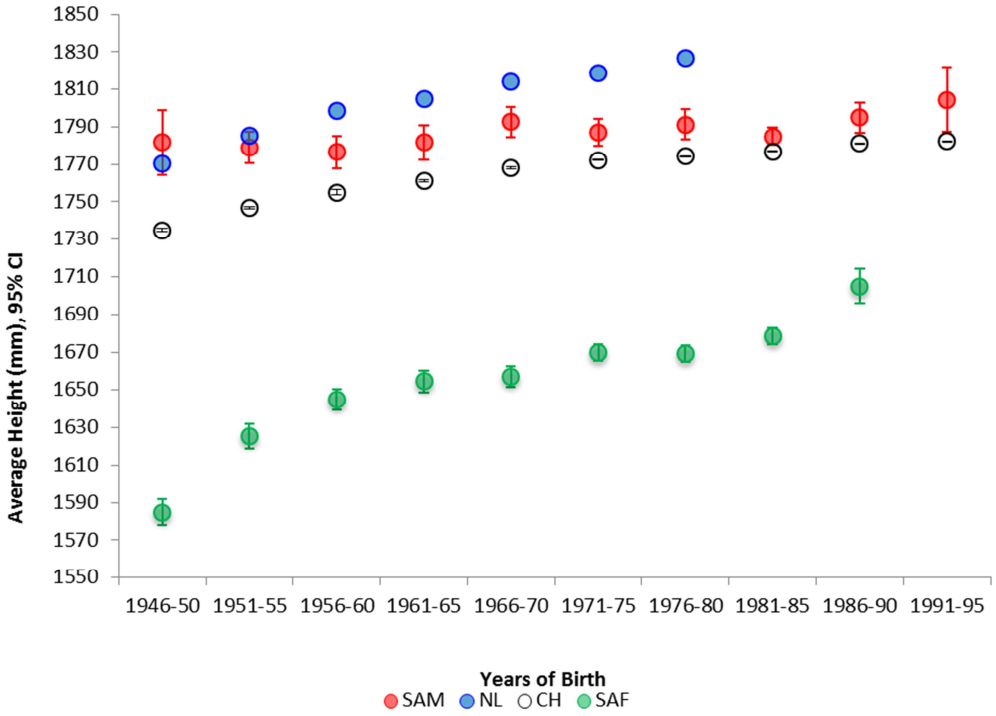

Fig. 1. Differences in the secular trends between white South African males (SAM) and females (SAF), Swiss (CH) and Dutch (NL) males over 5 year periods**.**